

## A STRUCTURAL ANALYSIS OF A CONNECTING ROD USING FEA

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### ABSTRACT

*The project mainly deals with the design, analysis and manufacture of connecting rod. The connecting rod is an integral part of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders among others with similar mechanisms. In an engine, the main objective of the connecting rod is to transfer force from expanding gas in the cylinder to the crankshaft. The design of the connecting rod and analyzing the manufacturing process of it. The temperature of connecting rod has a significant influence on efficiency, emission, performance of the SI engine. The purpose of these studies is to measure the transient temperature of connecting rod at different points on the connecting rod, from cold start to steady condition and compare those values with the standard results of finite element analysis. In this project, the connecting rod is modelled and assembled with the help of SOLID WORKS software and the component is meshed and analysis is done in ANSYS software and the modal and static behaviour is studied and the results are tabulated. The various stresses acting on the connecting rod under various loading conditions have been studied. In the present work, the focus on the following aspects is to overcome the research gaps and to display the results based on the systematic studies:*

- *Different modes of deformations for the connecting rod of an engine.*
- *FEA software to measure stresses at different points and to observe the behaviour of the connecting rod.*

**KEYWORDS:** ANSYS Software, Connecting Rod & SI Engine

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### INTRODUCTION

The connecting rod is an integral part of an S. I engine. It transfers the linear motion of the piston to the rotatory motion by transferring the thrust of the piston to the crankshaft. One end of the connecting rod is connected to the piston by the piston pin. The other end revolves with the crankshaft and is split to permit it to be clamped around the crankshaft with the help of bolts. The mass fuel combustion, which takes place in the chamber of the cylinder and piston generates tremendous amounts of force. Which result in pushing and pulling of connecting rod, generating axial and bending stresses. Bending stresses appear due to eccentricities, crankshaft, case wall deformation, and rotational mass force. A connecting rod is subjected to many millions of repetitive cyclic loadings. So the failure is inevitable, the research and development of a connecting rod is needed to improve to optimal level.

### Creation of Solid/Surface Bodies

A solid body is created by extruding the sketch geometry and to develop associate the features or creating the resemblance for the basic building blocks, then we can add more exact features to the bodies.

Shafting the sketch and non-sketch geometry allow us to make a solid body with complex geometry. Using this method, we can get a total control over the editing of the body. If there is any change in the model, we can directly change the sketch in part only, thus it automatically gets changed in all the part and assembly drawings. Dress-up features are used to modify the part bodies in response to the given specifications and are the most important advanced features to modify the objects through solid works.

## MODELLING PROCEDURE

### Connecting Rod Shank

To create the above part following features are used.

- Part
- Assembly
- Drawing

Open Solid works Software

To enter into any one of the module.

- Start Menu
- New
- Part Design
- It opens

To set the required units go to

- Tools menu
- Options
- Select units as mm.

To draw the sketch as per the specifications

Select required plane – select sketch tool, it enters into sketch module now draw the required sketch fatigue is one of the important factor which has been taken into consideration while optimizing an existing design as shown in Table 1. Fatigue within a component arises because of the following factors:

- Defects in material
- Defects in fabrication
- Improper defining of dimensions while designing

- Load calculation errors

**Table 1: Percentage of Stress**

Unsuitable raw material selection	36.99%
Fatigue	24%
Manufacturing errors	15.99%
heat treatment	9%-14%
Design mistakes	12%

The material selected for making the connecting rod is steel and aluminum and the properties of these materials are presented in the Table 2.

**Table 2: Properties of Selected Materials**

Parameters	MS	Aluminium
€	1.78e+005Mpa	70 Mpa
Density	7.197e-006Kg/mm <sup>3</sup>	2.61161 Kg/mm <sup>3</sup>
Poisson's Ratio	0.3	0.33
Compressive Strength	400 to 1000 Mpa	363 Mpa
Shear Strength	120 Mpa	90 Mpa
Tensile Strength	100 to 200 Mpa	422 Mpa

## CAD MODEL OF CR

Using CATIA, the geometric model of the CR is designed. There is a transition zone between small end and shank, center shank and a transition between big end and shank. Transition zones represents the stress concentration zones due to change in cross-section

**Table 3: Engine Specifications for using the Connecting Rod**

Parameters	Dimensions
Crank length	64mm
Stroke	58.6mm
Bore	57 mm
Maximum torque	13.4Nm @1600 revolutions/ min
Maximum power	13.8bhp @8500 revolutions/ min
Top speed at idle	2875 revolutions/ min
Top speed at full load	2500 revolutions/ min
Normal value of firing pressure	120 bars or 12 Mpa
Compression ratio	9.35/1
Peak firing pressure of the engine	130 bar or 13 Mpa
Center-to-center connecting rod length	233mm
Inner Diameter of Small end	19mm
Outer Diameter of Big end	50mm
Inner Diameter of Big end	40mm
Outer Diameter of Small end	22mm
Length of connecting rod	117.2

## Dynamic Equivalent System on Connecting Rod

Continuous body may be replaced by a body by two masses assumed to be concentrated at two points connected rigidly together. Such a system of two masses is termed an equivalent dynamical system. The conditions which should be satisfied by an equivalent system are:

- The total mass must be equal to that of the mass of a rigid body.
- The CG should coincide.
- The total MOI about an axis through CG must be equal

Dynamic Equivalent System of Connecting Rod:

Stroke length = 58.6mm, Diameter piston = 56, Length of connecting rod = 233,

Compression ratio = 9.35: 1; Pressure = 13 Mpa;

At maximum speed  $W_{\max} = 2\pi \times 3875 / 60 = 405.78 \text{ rad /s}$

At minimum speed  $W_{\min} = 2\pi \times 2500 / 60 = 261.79 \text{ rad/s}$

$$F_1 = mR \omega^2 \max r (\cos\Theta + \cos 2\Theta/n)$$

Where  $\Theta = 00$ ;  $n = 7.95$ ;  $r = 58.6/2 = 29.3$ ;  $F_1 = (1.6) \times (301.6)^2 \times 29.3(1 + 1/7.95)$ ;  $F_1 = 4783.54\text{N}$

#### Mass of Rigid Body by using Dynamically Equivalent System

$M =$  mass of the rigid body

$$m_a + m_b = m$$

$$m_a \cdot a^2 = m_b \cdot b^2 = mk^2$$

$$m_a = mb/a+b$$

$$K^2 = ab$$

$$K^2 = (58.2)^2$$

$$K = 58.6$$

$$M_a = 0.11 \times (58.6)^2 / 58.6(58.6 + 58.6)$$

$$M_a = 55\text{kg}$$

$$I_1 = 0.055(58.6)^2 + 0.055(58.6)^2$$

$$I_1 = 375.15$$

$$I_1/m = mk^2$$

$$k^2 = 375.15 / 0.11 = 3410.45$$

Radius of gyration =  $k_1 = 58.6$

$$a+b = 233 + 80/2 + 44/2$$

$$= 390 + 80 + 44/2 = 0.29\text{m}$$

$$\therefore a = 0.29 - b$$

$$t_a = 2\sqrt{L_a} / 9.81$$

$$\therefore L_a = 0.19$$

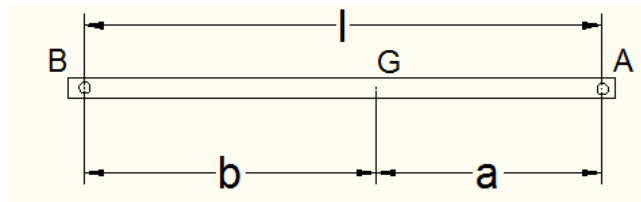


Figure 1: Inertia of Connecting Rod

$$\text{Moment of inertia} = mk^2 = 55 \times (0.358)^2 = 7.04$$

$$L_b = 8.9 \times 10^{-3}$$

$$k^2 = L_a \times a - a^2 = L_b \times b - b^2$$

$$= 0.011 - 0.039b - (0.084 - 0.58b + b^2) = 8.9 \times 10^{-3}$$

- $0.53b = 0.073$
- $b = 0.13$
- $a = 0.29 - b$
- $a = 0.29 - 0.13 = 0.16$

$$k = 0.029\text{m}$$

$$I_1 = mk^2 = 55 \times (0.029)^2 = 0.046\text{kg} \cdot \text{m}^2$$

$$b_1 = 110 - (44/2) = 88\text{mm}$$

$$d = k^2/b_1 = (0.97)^2/88 = 0.010\text{m}$$

$$m_d = m \times b_1/b_1 + d$$

$$= 49.99 \text{ kg}$$

$$m_{1b} = 55 - 49.99 = 5.01\text{kg}$$

Where  $m_{1b}$  = mass at the same end bearing center.

Analytical method

$$\omega = 2\pi N/60$$

$$= 261.9 \text{ rad/s}$$

$$\text{Mass of crank pin } m_a = 50 \times (233 - 117.2)/233 = 24.84 \text{ kg}$$

$$\text{Mass at gudgeon pin, } m_b = 55 - 24.84 = 30.16 \text{ kg}$$

$$\text{Total mass of reciprocating parts, } m = 15.69 + 30.16 = 45.85\text{kg}$$

$$\text{Acceleration of the reciprocating parts, } f = r\omega^2(\cos\theta + \cos^2\theta/n)$$

$$F_b = mf = m r \omega^2 (\cos\theta + \cos^2\theta/n)$$

$$F_b = 45.75 \times 0.05 \times (261.9)^2 (\cos 300 + \cos 600/4) = 54549 \text{ N}$$

$$T_b = F_r (\sin \theta + \sin 2\theta / 2\sqrt{n^2 - \sin^2 \theta})$$

$$= 54549 \times 4 (0.5 + 0.86/2\sqrt{16 - 0.25}) = 1326.6 \text{ N.m}$$

$$\Delta T = m \alpha c b (1 - L)$$

$$b = 233 - 117.2 = 115.8 \text{ mm}$$

$$L = b + k^2/b = 115.8 + (0.029)^2/115.8 = 115.8$$

### Correction Couple

- Correction couple must be applied in the opposite direction to that of the applied inertia torque.
- The direction of the angular acceleration is always opposite to the direction of the applied inertia torque.
- The direction of the correction couple will be the same as that of the angular acceleration in the direction of decreasing angle  $\beta$ .
- The correction couple will be generated by two equal, opposite and parallel forces  $F_y$  acting at the gudgeon pin and crank pin ends perpendicular to the line of the stroke.

### Modelling of the CR

Modelling of connecting rod using solid works software for 3D design using the theoretical calculations. The main conditions are applied with section view of a connecting rod as I-section.

Considering these dimensions re-designed this connecting rod. This connecting rod approved and used for some kind of bike as connecting rod? The sketch of this connecting rod drafting was shown below.

This connecting rod is divided into various parts such as:

- Body
- Ware plate
- Upper end ware plate
- Lower end ware plate
- Bolt nut

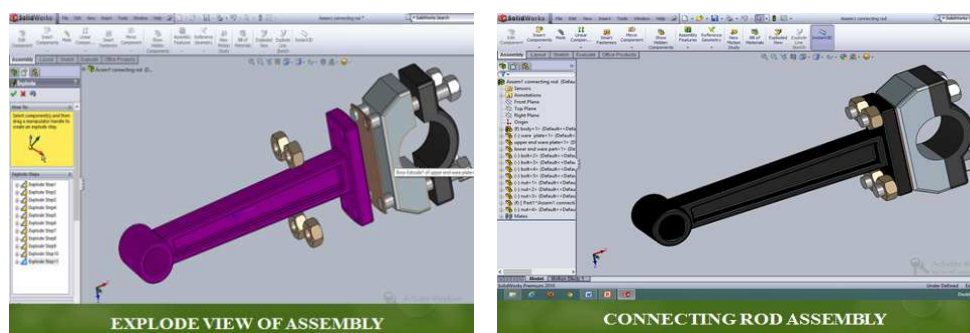


Figure 2

## Drafting of Connecting Rod

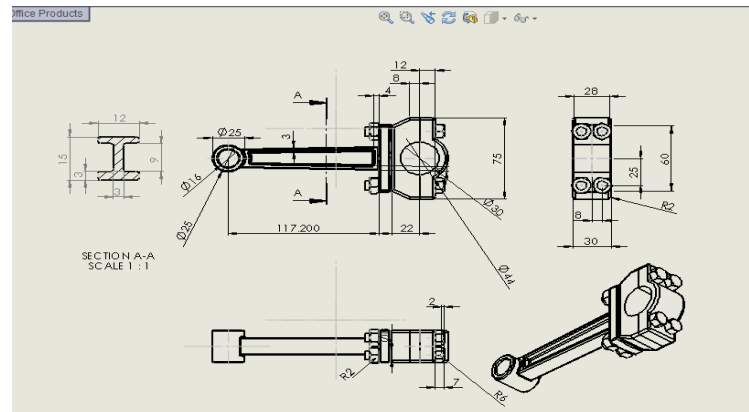


Figure 3

## Mode of Deformation

The part of this analysis was done by Ansys 14.0. This deformation for the connecting rod is shown from mode 1-6

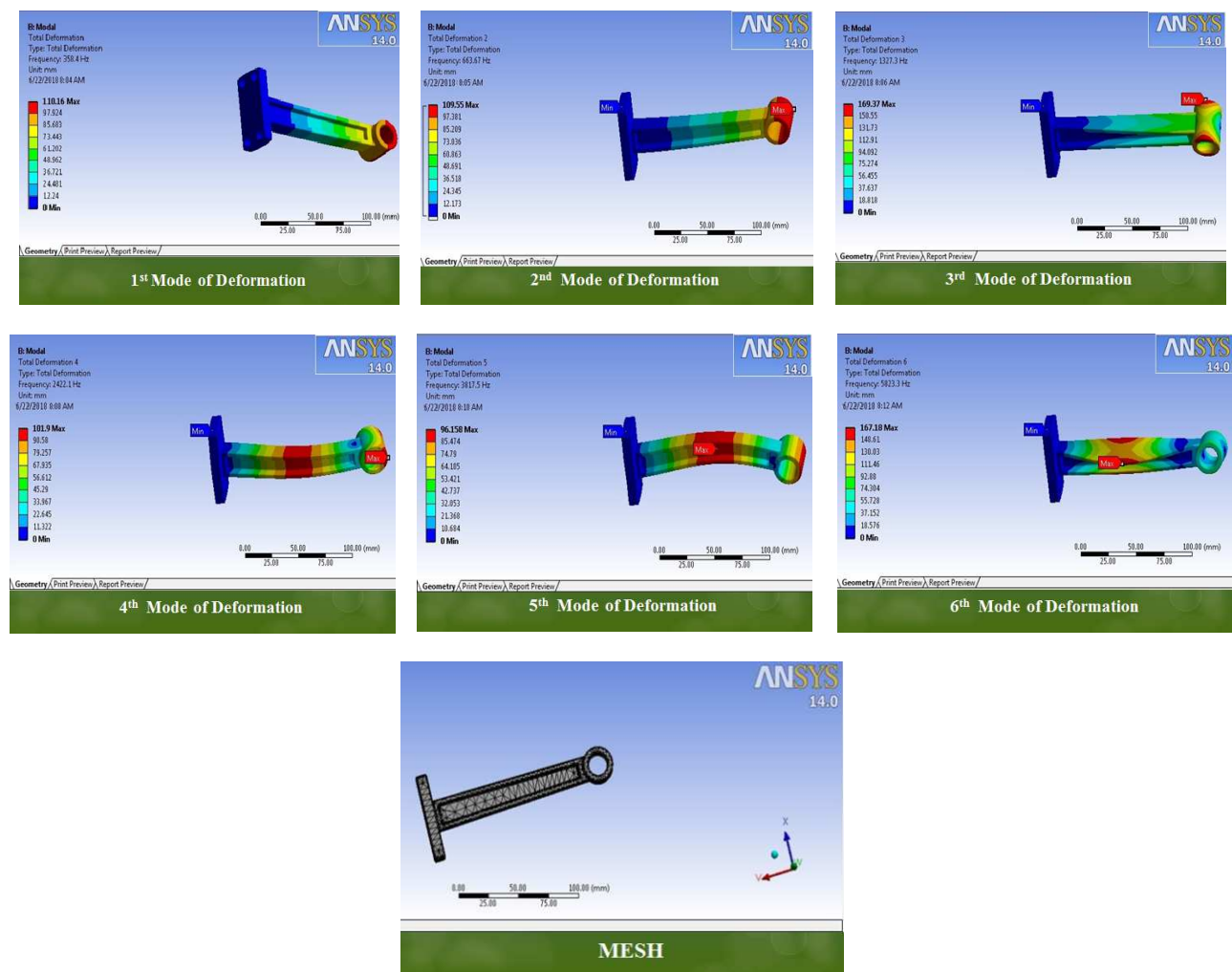


Figure 4



### Equivalent Stress with Applying Different Loads

The design of connecting rod with complete assembly was taken to the Ansys 14.0 version software and applying different loads upon it at various positions and find the stress and bending moments and describe it with pictures given below:

Structural analysis for Aluminium material both equivalent stress and total deformation are shown below

Loads applied as 500N–2500N.

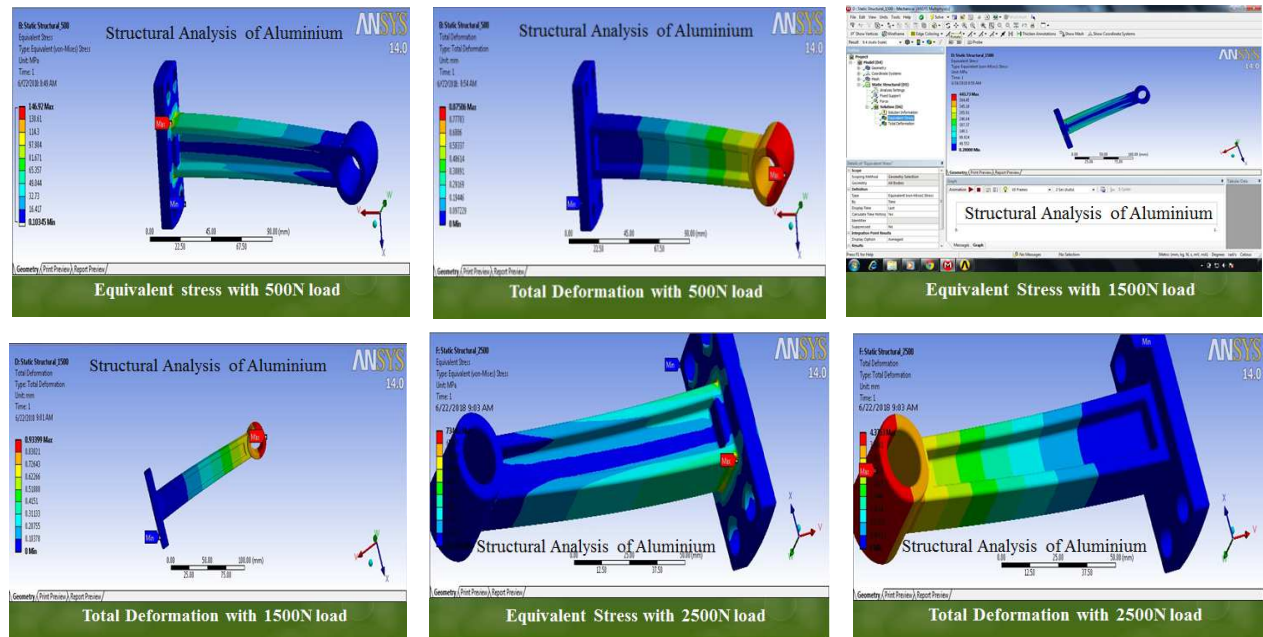


Figure 5

### Structural Analysis of Steel

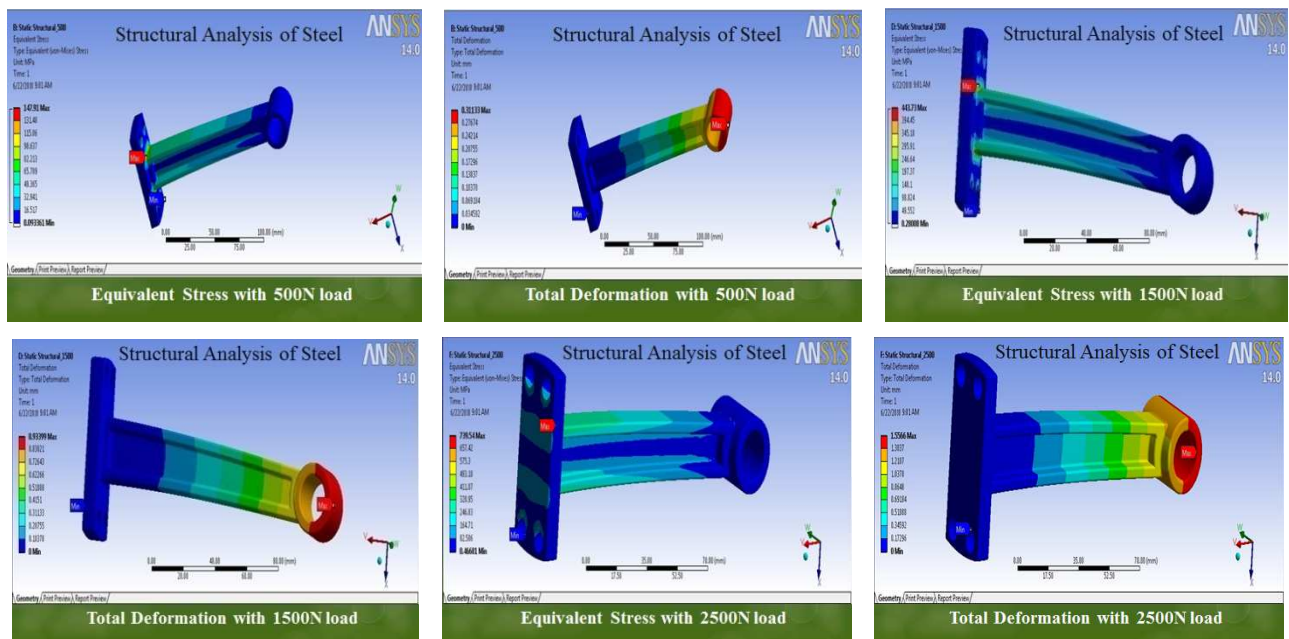


Figure 6



## RESULTS AND DISCUSSIONS

### Modal Analysis

Table 4: Modal Analysis

Mode	Frequency
1	358.4Hz
2	663.67 Hz
3	1327.3 Hz
4	2422.1 Hz
5	3817.5 Hz
6	5823.3 Hz

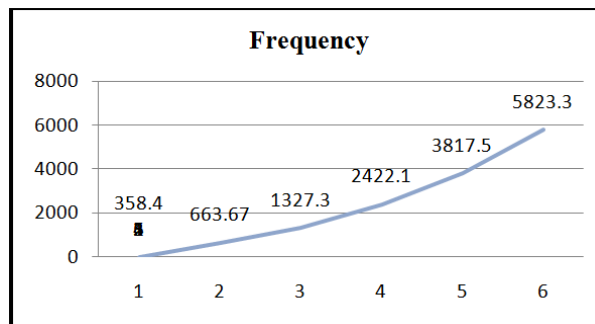


Figure 7: Mode Vs Frequency's

### STATIC ANALYSIS

Table 5: Static Analysis for Steel and Aluminum

S. No	Load (N)	Steel		Aluminum	
		Equivalent Stress (M pa)	Total Deformation (mm)	Equivalent Stress (M pa)	Total Deformation (mm)
1	500	147.9	0.31	146.9	0.87
2	1000	295.8	0.62	293.8	1.75
3	1500	443.73	0.93	493.9	2.93
4	2000	591.64	1.24	587.7	3.50
5	2500	739.54	1.55	734.6	4.37

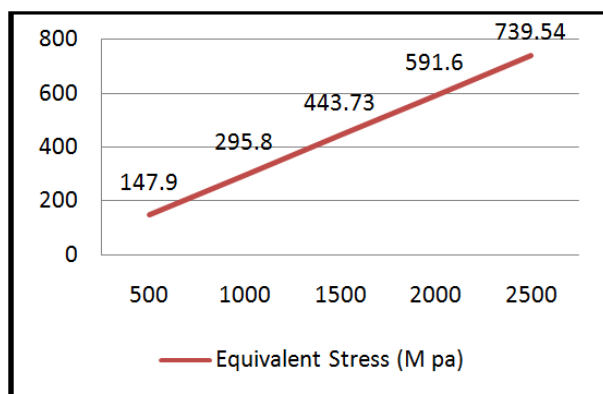


Figure 8: Load Vs Equivalent Stress Steel

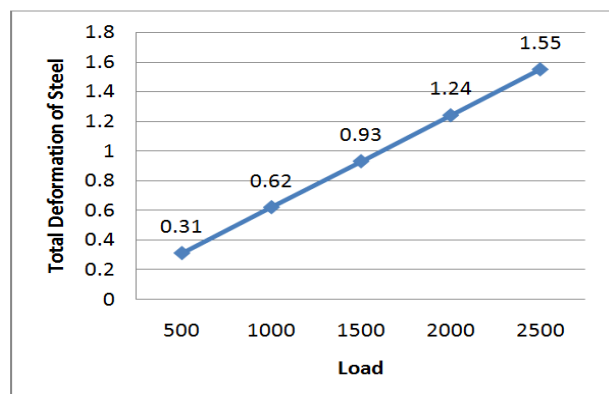
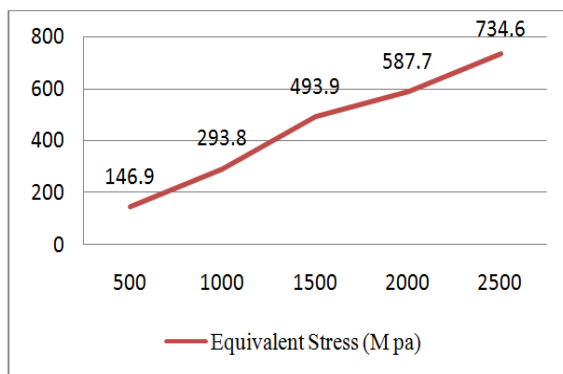
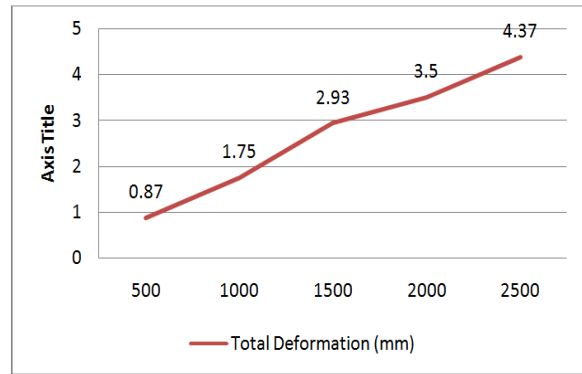


Figure 9: Load Vs Total Deformation of Steel



**Figure 10: Load Vs Equivalent Stress of Aluminum**



**Figure 11: Load Vs Total Deformation of Aluminum**

## CONCLUSIONS

By analysing and comparing the output obtained from different materials, the final results are achieved. In this thesis is, the connecting rod was created in SOLID WORKS. The model which is created by SOLID WORKS premium 2010 was then imported to ANSYS14.0 software. The maximum deformation appears one at the small end bearing the inner fiber surface & the other at the center of big end. After implementing boundary conditions, the areas subjected to crushing due to crank shaft & gudgeon pin is shown by carrying out the analysis. Bending is dominant for connecting rod deformation occurs mainly due to buckling under the critical loading. Also, the maximum deformation was obtained due to crush & shear failure of the big & small end bearings. So, these areas appear to be prone to the fatigue crack. Based on these results, we can assume the possibility of mutual assembly between the connecting rod and other parts.

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